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ABSTRACT

Two-column objectives are listed for an integrated science curriculum (Grades K-12), often subheaded according to science area (physical sciences, physics, biology, chemistry, general science) and grade level. Objectives that relate characteristics and forms of energy to energy conservation are stressed in the primary grades (K-6). In grade 7, the objectives are grouped for the study of energy, photosynthesis and the nervous system; other non-integrated topics include Newton's laws of motion, electrical circuitry, heat energy, mechanical energy, sound, weathering and erosion. Objectives concerning the study of radiant energy, nuclear energy, electric energy, and molecular theory are included for grade 9. An attempt is made in grades 10-11 to relate chemistry and physics to the study of living things. Non-integrated objectives are written for grade 11 in earth science and for grade 12 in physics. (CS)

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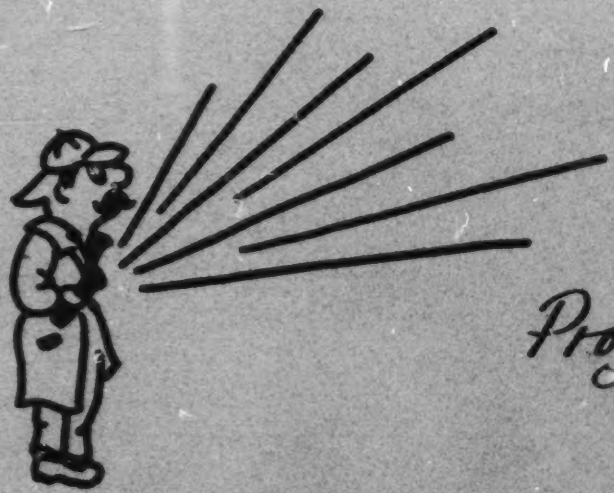
Articulated Curriculum



Project Search

1975

Draft Copy

SE 021 926

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FORWARD

This Articulated Curriculum is being printed and bound in this manner to provide for on-going revision. This also serves as evidence of work completed during Phase III of Project SEARCH.

SCIENCE

K - 12

CONSERVATION OF ENERGY

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PROJECT SEARCH

ARTICULATED CURRICULUM

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August 1975

MRS. ROSE DANELLA and NORMAN I. SIEGEL, both former Board Members deserve special mention for all their efforts on behalf of Project SEARCH.

UTICA CITY SCHOOL DISTRICT
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SCIENCE

CONSERVATION OF ENERGY

The student will know:

- that there are many kinds of energy
- that some energy cannot be seen.
- that energy is force.
- that magnets exert energy.
- that energy cannot be seen.
- that iron and steel things are attracted to a magnet.
- that when a fuel burns, energy is released.
- that energy is the ability to do work.

Grade K

The student will:

- enumerate energy producers (coal,oil,etc.)
- identify a magnet and list its uses orally.

Grade 1

- explain what happens when something is pushed or pulled.
- name some things magnets will pick up.
- explain that agents creating energy can be seen but energy itself is not targible.

Grade 2

- differentiate between materials that are magnetic and those which are non-magnetic.
- draw a picture to show that wood gives out heat and light while it is burning.
- identify fuel and show how some forms of energy are produced. (ex. rocket fuel)
- enumerate the many ways heat is produced as energy. (boiling water, etc.)

Grade 3

- recite verbally his understanding of the definition..

- that energy has different forms and can change from one form to another.
- the uses of the different forms of energy.
- that the sun is a major source of energy.
- that other natural sources of energy are derived from the sun ie. oil and coal.
- that moving air and water exert energy.

- that change in state can be explaind in terms of molecules and energy.
- that energy appears in various forms.
- that loss or gain of Energy effects molecular motion.
- that energy can change from one form to another.

- that energy must be applied to produce an unbalanced force, resulting in motion or change of motion.
- that energy is the ability to work; it exists in different forms, and can be changed from one form to another.

- name 3 different forms of energy and illustrate a change that can occur in each.
- match an object to its use.
- draw and demonstrate the evaporation cycle.
- demonstrate verbally and by experimentation their understanding of these other natural sources of energy.
- demonstrate how air pressure is used to do work.

Grade 4

- identify cause and effect in changes of state. (finding energy from various sources.)
- list ways to use energy to change state of matter. (Boiling, etc.)
- classify energy according to its state.
- explain various forms of energy. (Demonstrate by an experiment one form of energy and how it works.)

Grade 5

- calculate the amount of work being done when given work problems using formula W = FxE.
- make a chart illustrating different forms of energy at work.
- make a model showing one form of energy at work.

- that man has various sources of energy: Solar, Nuclear, Electric, Organic Fuels.

- the causes and effects of energy shortages.

- that it is necessary to use solar energy.

- that it is necessary to conserve nuclear energy.

- that it is necessary to conserve heat energy.

- that it is necessary to conserve sound energy.

- that it is necessary to conserve electrical energy.

- the forms of energy.

- report on the forms of energy, and list their sources, uses, and advantages.

- discuss with group ways of conserving energy at home, school, and in the community.

- identify examples of wasted energy.

- report to class on how energy may be conserved.

- list in a paragraph ways solar energy can be used instead of fossil fuels, (gas, coal, oil) to heat a home.

- describe in mathematical terms the differences in amounts of energy used in producing energy from fossil fuels and nuclear energy.

- list places insulation should be used to conserve heat energy in the home.

- list ways in which "noise" could be controlled.

- list 20 electrical things that are not necessities for modern man's survival.

- select from a collage the various forms of energy.

- explain the difference between natural and artifical light.

- list ways in which heat is conducted e.g. conduction, convection, radiation.

- define the characteristics of sound e.g. pitch, intensity, and tone.

- list the differences between sources of electrical energy: wet cells, dry cells, storage batteries, [illegible]

General Science

- what an energy pyramid is, by definition.
- the various parts of an energy pyramid.
- why an energy pyramid "Peaks".

Photosynthesis:

- the mechanism by which green plants capture the sun's energy and store this energy in molecular form.

- the ability to do work is called energy. Man's nervous system directs his use of energy, into his behavior.

- write examples of various areas which use nuclear energy; e.g. Genetics, production of electricity, trasportation, medicine, agriculture, water supply, geology.

Grade 7

- list factors entering into an energy pyramid.
- draw and label an energy pyramid.
- list energy "losses" from one energy level to another.

Define photosynthesis.

- list the types of energy generated by the sun.
- define the sun as our sole source of energy in our solar system.
- list the types of energy (on the electromagnetic spectrum) utilized by green plants in photosynthesis.
- draw a picture of a chloroplast and label it.
- name the chlorophyll molecule as the energy capturing molecule.
- draw a flow chart of energy in the photosynthetic process.
- dissect a frog and identify the parts of the nervous system.
- diagram the 3 parts of the brain and list their functions.
- make a model of a neuron using plastic clay.
- make a model of the human brain and map the various parts and their functions.

- factors in man's physical environment influence his behavior. These stimuli result in a response. The formula for "Behavior" is Stimulus-----Response

or

S----------R

- the largest part of the brain is the Cerebrum. The Cerebrum is also the thinking part of the brain, and controls thought, memory and learning.

- the Sense Organs receive stimuli from the environment. These stimuli influence man's behavior.

- distinguish between man's voluntary acts and his involuntary acts.

- be able to explain the formula S—R giving examples of 5 stimul with an appropriate response for each.

- be able to distinguish between a learned response and a reflex; between a reflex and an instinct.

- be able to diagram the reflex arc.

- be able to set up a conditioning experiment.

- be able to distinguish between judgement, reasoning and memory.

- be able to locate the part of the brain that controls memory.

- be able to discuss how he could develop habits that would help him in learning.

- explain the trial and error method of learning.

- be able to name the five senses and the sense organ involved with each sense.

- be able to diagram the five sense organs and label all parts.

- be able to discuss the similarities between the eye and the camera.

- be able to explain how stimuli are received by the sense organs, sent to the brain and interpreted.

- define sense, sensation, sense organ.

- distinguish between OPTIC Nerve and AUDITORY Nerve.

- behavior is controlled by Man's central nervous system. The central nervous system consists of the Brain, the Spinal Cord and the Nerves.

- the mechanics of getting man into space keeping him there and returning him safely to earth in a space vehicle.

- that an electrical current is a flow of electrons through a conductor.

- that a complete electrical circuit is one which has an unbroken conductive path.

- be able to distinguish between the cerebrum, the cerebellum and the medulla oblongata, by locating the parts on a diagram of the brain.

- list the functions of the 3 parts of the brain.

- explain the relationship between convolutions of the brain and intelligence.

- be able to explain how an injury to the brain or spinal cord or nerves could affect behavior.

- give the number of head nerves and spinal nerves.

- write Newton's first law of motion and relate it to getting a space vehicle away from earth's gravity.

- write Newton's second law of motion and relate it to acceleration and decceleration in space flight.

- draw a diagram illustrating Newton's second law of motion.

- write Newton's third law of motion and relate it to a space vehicle escaping earth's gravity, changing course in space and returning to earth.

- draw a diagram illustrating Newton's third law of motion.

- define in writing that a conductor is any substance through which electricity will pass.

- given a list of substances, student will select those which are conductors of electricity.

- define an electrical current as a flow of electrons through a conductor.

- define an electrical circuit as the complete path through which an electrical current flows.

- Give a diagram of an incomplete circuit because of an unconnected wire and asked whether or not a component of the circuit (motor, bell, light) will be activated and to explain his response, student will answer negatively to the question and explain that the component will not be activated because the circuit is not complete.

- given wires, a light bulb, and a dry cell battery, student will be able to connect the materials in a simple circuit so that the bulb will light.

- that a series circuit is a circuit such that electricity must travel through all parts of the circuit and that a parallel circuit is a circuit which provides more than one path in which electricity can flow.

- given a size "D" battery, two #222 bulbs in sockets and three test leads or wires and asked to connect the bulbs in series student will connect the components so that the current flows through them in succession.

- when asked to diagram an operable circuit contains a switch, a battery and 3 motors wired in series, the student will diagram the circuit to show that relationship.

- Given a size "D" battery, two #222 bulbs in sockets and four test leads or wires, student will connect the components so that the current flowing through it need not pass through the other components.

- when asked to diagram an operable circuit containing a battery and 3 motors connected in parallel, student will diagram the parallel circuit.

- given diagrams of two parallel circuits and two series circuits and asked to classify each as either parallel or series the student classifies them as directed.

- that electrical energy can be converted into other forms of energy and vice versa.

- state 2 examples in which electricity is used to perate an electrical device in h which an object or part of it gains mechanical or kinetic energy (electrical fan).

- state 2 examples in which electricity is used to operate an electrical device in which an object gains or releases light energy (electrical lamp).

- state 2 examples in which electricity is used to operate an electrical device in which an object gains sound energy (radio).

- state 3 examples in which electricity is used to operate an electrical device in which an object gains heat energy (iron, stove).

- list three energy converters found in his home and state the energy changes involved in each.

- state an example in which chemical energy is changed to electrical energy (dry cell battery).

- state an example in which mechanical or kinetic energy is changed to electrical energy (turbine).

- that temperature is the measurement in degrees, of the hotness or coldness of an object and is measured by a thermometer.

- define temperature.

- measure the temperature of a substance within an accuracy of +1 degree using either a Fahrenheit or Celsius thermometer.

- describe how a liquid-in-tube thermometer works. (liquid expands as temperature increases and contracts as temperature decreases).

- tell in writing that water freezes when temperature on a thermometer registers 0° Celsius or 32° Fahrenheit.

- tell in writing that water boils when temperature on a thermometer registers 100° Celsius or 212° Fahrenheit.

- that heat is a form of energy which when added to a substance changes its temperature and is measured in calories.

- define heat energy.

- define calorie as the measure of heat energy needed to raise the temperature of 1 gram of water 1° Celsius.

- that whenever two objects at different temperatures are in contact with each other, heat flows from the hot object to the cooler one until an equilibrium is reached.

- that substances expand when heated.

- that heat energy can be converted into other forms of energy and vice versa.

- that a <u>force</u> is a push or pull on an object which changes that object's shape or motion and is measured in newtons or pounds.

- That work in the language of science is not the same as work as we commonly know it.

- Calculate the number of calories of heat required to raise the temperature of a given mass of water using the relationship amount of heat = mass of water x change in temperature.

  (in calories) (in grams) (in degrees)

- indicate with arrows on a diagram the heat flow, when several container of varying temperatures are placed in contact with each other.

- find the equilibrium temperature of two containers placed in contact with each other, given the initial temperature of each.

- describe how a liquid-in-thermometer works.

- state that substances expand the most in the gaseous state, slightly in the liquid state, and very little in the solid state.

- describe three ways in which heat can be changed to another form of energy.

- describe three ways in which some form of energy can be converted into heat energy.

- define force

- measure weight of objects with a newton scale.

- identify the following forces as used in examples: weight friction, inertia, magnetic.

- the student will define work as a force succeeding in moving a body through a distance.

- that mechanical energy is the ability to do work and is measured by the amount of work that body can do.

- that machines enable man to transfer energy from one place to another and to tranform energy from one form to another.

- student will calculate work done on an object given the force acting on that object and the distance that object moves using the relationship

  Work = Force x Distance

- define mechanical energy.

- define potential energy as stored energy of a body due to its position.

- identify or give examples of objects with potential energy.

- calculate the potential energy of an object given its weight and its distance above the ground using the relationship potential Energy = Weight x Height.

- define kinetic energy as the energy a moving body.
- Calculate kinetic energy gained by an object in falling by using the relationship

  Total mechanical energy (greatest PE) = Potential energy + Kinetic energy

  Kinetic energy = Potential Energy (initial) - Potential Energy (at certain point)

- identify the six simple machines: inclined plane, lever, pulley, wedge, screw, wheel & axle.

- describe how each of the six simple machines help us do work by either multiplying or changing the direction of a force.

- calculate input work done on a machine given force and distance measurements.

- calculate output work done by a machine given force and distance measurements.

- calculate the mech[illegible]

- that all sound is caused by vibration.

- the meanings of important sound terms such as air column, vibration, echo, pitch, frequency, compression and rarefaction.

- that sounds beyond the range of human hearing are called ultrasonic sounds.

- that sound travels at different speeds through different mediums and not at all through a vacuum.

- calculat the efficiency of a machine EFF = $\frac{\text{Work output}}{\text{Work input}}$

- explain that no machine can be 100% efficient because some input work is always used to overcome friction in a machine.

- perform the following tasks and verbally identify the vibrations:
  - strum a guitar
  - scratch a door
  - rub hands together
  - hit the desk
  - blow a whistle
  - shake a jar of marbles
  - strike a drum
  - feel the throat when speaking

- demonstrate the phenomenom that physicists call "sympathetic vibration" by performing the musical fork experiment.

- read and write the definitions of the words in the "sound" "vocabulary".

- use these sound terms correctly when responding in class discussions.

- use these sound terms correctly when writing answers to questions assigned from textbook chapter.

- write and memorize the range of human hearing in vibrations section.

- read the text chapter on ultrasonic sounds.

- list in writing the different speeds at which sound travels through such mediums as air, water and steel.

- that when a sound is made, air molecules vibrate and form a pattern where they press together and spread apart in waves.

- that echoes are the bouncing back of sound waves.

- rocks are weathered mechanically through temperature change, frost action and the action of plants and animals.

- Demonstrate with a friend that sound travels better through the air by sitting at opposite ends of a table and tapping the desk and then listening to the sound with your ear on the table.

- view a movie which illustrates how Indians used the above principle and put their ears to the ground to hear if buffalo were nearby or if horses were coming.

- perform the ringing alarm experiment which proves that sound will not travel in a vacuum.

- draw a model of a sound wave and label the compressions and the rarefactions.

- draw a model of a sound wave and label the compressions and the rarefactions.

- perform the slinky spring experiment with a slinky spring to demonstrate the behavior of sound waves in air.

- pluck and observe a tuning fork.

- shout in a pail to hear his voice reflection come back real fast.

- shout in an empty hall and listen to the echo.

- read with the class how ships use sound reflections to find ocean depths.

- perform an outdoor experiment with the class which will illustrate the effects of different environments or echoes.

- effect of extreme temperature change on rock.

- the student will do experiments using heat and cold to show how these effect weathering of rock.

- frost action is a greater force in weathering than heat and cold.

- the student will be given iron pipe threaded and capped which is to be filled with water and placed in freezer for observation.

- the effects of plants and animals on rock materials.

- the student will be asked to observe his community for signs of animals and plants affecting rock.

- mechanical weather occurs when a rock formation is broken apart by various forces.

- be taken on a field trip to observe different forms of weathering.

- the force of gravity through the process of erosion moves materials to new locations.

- be shown slides taken during the summer that demonstrate how rock is moved by gravity, wind and water.

- the processes of chemical weathering:
  particle size reaction to acid.
  oxidation
  effect of CO 2 in water produces carbonic acid.

- do experiments using HCl and lime stone. Field trip will be taken to Clinton area so that students can observe results of oxidation on iron compound in rock surface. Student will do experiment to show effect of carbonic acid on limestone.

- how climate affects chemical weathering.

- pictures and slides will be shown to student to demonstrate that weathering differs under different climatic conditions.

- how stalactites and stalagmites are formed.

- a demonstration using epsom salts will be used to show the formation of stalactites and stalagmites.

- the effects and controls of erosional forces.

- student will be shown slides of soil conservation practices to prevent erosion and others to show how erosion occurs when these are missing.

Grade 9

- that light is a form of energy which is known as radiant energy.

- draw a transverse wave showing its direction.

- identify frequency and wave length by performing experiments dealing with waves.

- that light travels thru space at a speed of 186,000 miles per second.	- solve mathematically the distance in miles involved in a light year.
- that the Quantum Theory of light is accepted by most scientists today to explain the wave motion of light.	- list the names of scientists who developed the theories of light.
	- draw the atom with its energy levels showing electromagnetic radiation with the release of light and energy.
- that the knowledge of the properties of electromagnetic radiations and the electromagnetic spectrum are necessary in the understanding of light.	- list the important properties of electromagnetic radiation.
	- draw and label a chart containing the electromagnetic spectrum.
- the explanation of the laws of reflection and refraction.	- draw and label a prism showing refraction.
	- list the spectrum showing the dispersion of white light into colored light.
	- draw and label the reflection from a smooth object labeling the rays, angles, and the normal.
	- draw and label a diffused reflection from a rough object showing angles.
- that the index of refraction depends upon different densities.	- solve problems relating to the index of refraction.
- that convex and concave lens are important to human sight.	- perform experiments involving convex and concave lenses to show conversion and divergence of light rays.
	- list the causes of farsightedness and nearsightedness.
- the historical development of nuclear energy.	- list the names and contributions of important scientists engaged in the development of nuclear energy.
- that nuclear reactors provide energy to a variety of uses.	- explain the fission (splitting) of U-235 in a nuclear reactor by labeled drawings.

- that nuclear fusion causes atoms to form elements of greater atomic weights and release energy in the process.

- the present and future uses of nuclear energy are beneficial and destructive to mankind.

- the different forms of energy that can help man to do work.

- how electricity is used to benefit man.

- construct a model of a nuclear reactor and label control rod, concrete shieldings; moderators, aluminum tubes and protective shielding using cardboard.

- list the names of particle accelerators used in smashing atom.

- draw and label the fusion process for Hydrogen.

- list the elements which are capable of fusing.

- identify the elements which are naturally radioactive.

- identify a radioactive substance by use of a Geiger Counter.

- explain artificial radioactivity by the use of charts.

- illustrate by graphs the half-life of radioactive elements.

- list the uses of radioisotopes in agriculture and industry.

- list the uses of radioisotopes in medicine to help control cancer

- list the destructive affects of an atomic bomb dropped on a city starting from ground zero and going out to 50 miles.

- list the different forms of electrical energy.

- diagram and label an electric current showing voltage, resistance, and flow.

- apply Ohm's Law to solve simple problems dealing with current flow.

- solve problems dealing with simple parallel circuit.

- solve problems dealing with series circuit.

	- explain how a generator makes electricity.
	- explain and diagram a dry cell and its parts.
- that matter is made up of tiny particles some of which are electrical in nature.	- label and draw the two main parts of an atom.
	- list the characteristics of the nucleus, protons, neutrons, and electrons.
	- demonstrate the magnetic effect of an electric current by using the proper equipment.
- the molecular theory of magnetism and how a magnet operates.	- draw a diagram of a magnet showing how molecules are arranged according to molecular theory.
	- explain difference between permanent magnet and temporary magnet.
	- demonstrate that like charges repel each other unlike charges attract each other.
	- explain how the magnetic field of the earth operates.
- that the earth is a magnet.	- show how a compass is affected by the earth.
	- describe uses of gyro compass.
	- describe the properties of electromagnets.
- how an electromagnet operates and how it can be used in beneficial ways by man.	- explain how the strength of an electromagnet is increased.
	- construct an electromagnet in a laboratory and show its uses..

Grade 10

Biology

- the relationship of chemistry and physics to the study of living things.	- compare and contrast neutral, basic, and acidic solutions.

- how an organism obtains energy in order to perform its functions.

- describe the PH scale and its use.
- state the law of conservation of energy.
- compare and contrast carbohydrates, liquids, and proteins.
- describe a major biological function of the nucleic acids.
- explain that organisms obtain usable energy by breaking the bonds of high energy molecules.
- describe the enzyme "lock and key" hypothesis.
- diagram the ATP-ADP cycle and explain what happens during the cycle.
- compare and contrast aerobic respiration and anearobic respiration.
- relate the details of respiration to the simple equation.
- compare and contrast the use of glucose by a cell and the use of fatty acids and amino acids.

Physical Science

- the many forms of energy that are interchangeable; one form changing to another but never being destroyed.
- the various conditions under which an automobile may stop safely for varying highway conditions.
- that velocity is equal to the distance divided by the time interval.

- be able to identify a linear relationship between two plotte functions as in a graph.
- be able to explain why an automobile traveling at 60 miles per hour is four times as dangerous as an automobile traveling at 30 miles per hour.
- be able to state the rule that work is equal to a force multiplied by a given distance and that both force and distance must be assigned a given direction.

- the mechanical advantage of a simple machine is always given in terms of a ratio.

- the difference between potential energy and kinetic energy.

- that when energy is released during any reaction, the reaction is said to be exothermic.

- be able to infer from given data that the relationship between the height above the floor at which an automobile starts and the stopping distance in the horizontal direction is a direct proportion.

- be able to identify at least four kinds of energy and show how each kind of energy operates.

- perform a simple experiment such as burning a piece of wood and measure the amount of heat absorbed by a weight amount of water (caloremeter).

- list a number of changes and obtain the handbook values given for each change listed.

Grade 10-12 ...../

Biological Science

- all living things constantly need energy.

- plants need CO 2 and light to make starch.

- plants need chlorophyll to maintain life.

- plants produce O 2.

- CO 2 is released when food is broken down for energy.

- living things need O 2 to release energy if life is to continue.

- burn a candle and various kinds of food to heat a measured amount of water. (to calculate a "candlecalorie")

- test for the presence of starch in plant leaves covered to prevent the entrance of CO 2 and other plant leaves kept in the dark.

- seperate chlorophyll pigments using the technique of proper chromatography.

- use a respirometer students will measure the output of a gas from a plant.

- predict after observing 2 tubes of yeast and design an experiment to explain why one is bubbling.

- measure the amount of O 2 used by a group of soaked and boiled pea seeds.

Earth Science

- that all objects not at a temperature of absolute zero radiate electromagnetic energy.	- measure units of electromagnetic energy in microns.
- that electromagnetic energy can be refracted reflected, cattered and absorbed.	- name and describe processes of energy transfer.
- the sun is the major source of energy for the earth.	- identify sources of energy.
- that conduction of thermal energy occurs as an interaction of matter at the molecular or atomic level.	- analyze processes of energy transfer.
- that changes of phase are contingent upon the loss or gain of energy.	- draw inferences about the conservation of energy.
- that a significantly greater amount of energy is required to change a given mass of water from liquid to vapor than is required to change ice to liquid.	- analyze environmental processes of phase change.
- the amount of energy lost by a source equals the amount of energy gained by a sink.	- describe energy transformation that has been observed in the environment.
- the movement of matter toward or away from the earth's center of mass results in an energy transformation from kinetic to potential or vice versa.	- draw inferences about the conservation of energy.
- water has the highest specific heat capacity among naturally occuring materials.	- construct a list of materials with their individual specific heat, include water.
- the intensity of insolation per unit area increases as the angle of insulation approaches perpendicular.	- measure intensity of insolation for different angle settings..

- the temperature at a given location varies directly with the duration of insolation.

- the atmosphere is largely transparent to visile radiation, but it selectively absorbs quantities of ultraviolet and infrred radiation.

- that clouds may select approximately 25% of incident insolation.

- that water vapor and carbon dioxide are good absorbers of infrared radiation.

- that air pressure changes are closely assciated with temperature changes.

- that variations in the dew point temperature are indicators of charges in atmospheric moisture.

- that windspeeds are directly related to presure field gradients.

- that probability of precipitation increases as the difference between dew point temperature and air temperature decreases.

- construct a chart with a given number of cities in northern and southern latitudes and the amount of daylight hours for each given date.

- analyze factors which influence the amount of insolation reaching the earth.

- construct a graph; cloud type verses incident insolation.

- draw up a list of atmosphere gases and observe their affect on infrared radiation.

- compare locally observed atmospheric variables.

- derive interelationships from local observations.

- measure wind speeds with earth science wind gauge.

- operate with accuracy a sling psychrometer in oder to determine a dew point temperature.

Physics

Grade 12

- that Kinematics deals with the mathematical methods of describing motion without regard to the forces which produce it.

- construct graphs of, and solve, Kinematic equations involving the scolars—distance, speed and acceleration and the vectors displacement, velocity and acceleration.

- construct graphs and solve equations which apply uniform acceleration to freely falling bodies.

- that ces are vectors and that forces may a through space.

- that amics deals with the relation betwe the forces acting on an object and the resulting change in motion.

- that hen work is done on or by a syste the total energy of the system is chged.

- that any treansfer of energy among objec in a closed system, the total ener of the system remains constant.

- thatinternal energy is the total Kinetic and otential energy associated with the mot ns and relative positions of the molcules of an object, apart from any Kinetic or potential energy of the object as whole.

- t u gases are composed of molecules in constant ranom motion.

- tha light exhibits the characteristics of waves and particles.

- solve both graphical and numerical problems involving the composition and resolution of forces.

- list the categories of forces.

- solve problems involving Newton's Laws of Motion and the Law of Gravitation.

- solve problems involving centripetal force and entripetal acceleration for uniform circular motion.

- solve problems involving the Conservation of Momentum.

- solve problems which involve the calculaltio of work, mechanical potential energy, gravitational potential energy, Kinetic energy and power.

- calculate mechanical energy transformations in situations without friction.

- calculate work done against friction in several situations.

- solve problems involving the mechanical equivalent of heat, change from one temperature scale to another, transfer of heat under conditions of temperature change, and/or phase changes.

- solve problems involving the General Gas Law, PV=NRT.

- solve problems relating the average Kinetic Energy of molecules with Absolute Temperature.

- list the wave properties of light.

- describe the photo-electric effect.

- that the Quantum Theory was developed to explain phenomena which could not be explained by the Classical Theory.

- the process of creating atomic models and will know details of the Rutherford Bohr model of the atom.

- that each element has a characteristic spectrum.

- that the necleus is the ore of the atom and contains most of the mass of the atom.

- the nature of many nuclear reactions.

- that wave is a vibratory disturbance that is propagated from a source.

- that wave motion transfers energy from one point to another with no transfer of mass between the points.

- perform graphical and numerical solutions of the photo-electric equation.

- describe the Compton effect and calculate photomomenta.

- calculate DeBroglie wave lengths for particles.

- describe the Rutherford Scattering Experiments and the conclusions made therefrom.

- describe the Bohr model and make energy level calculations.

- show how the hydrogen spectrum can be related to the Bohr Model.

- calculate wavelengths for the Balmer Series from the Balmer equation.

- list the observational tools and show how experiments and observations lead to the concepts of:
  nucleus
  atomic number
  mass number
  nuclear force
  nuclear mass and isotopes
  binding energy
- describe the details of:
  natural radioactivity
  half life
  Einstein's mass-energy equation
  indirect transmutation
  nuclear fission
  nuclear fusion

- produce waves in a stretched spring.

- explain through an example this phenomenom.

- the diference between longitudinal and transvrse waves.

- the chracteristics of periodic waves (frequncy, period, speed, amplitude, phase, wave length).

- the difference between dispersive and non dispersive media.

- that: wave front is the locus of adjacent points of the wave which are in pase.

- the law of reflection.

- thatimages formed by a plane reflecting surface is virtual, erect, and the same size as the object; object and image distance are equal.

- that refraction is the change in the direction of a wave that occurs when the wave passes obliquely through a boundry with a change in its speed.

- produce longitudinal and transverse waves in a slinky.

- calculate freezing, speed, wave length using the formula $v = f$

- measure the wave length of water waves in a ripple tank.

- calculate the period of a wave using the formula $T = \frac{1}{f}$ product waves of different amplitude in a stretched spring.

- write the definitions of dispersive and nondispersive media.

- name a dispersive medium for light.

- construct wave front and ray diagrams.

- produce reflection patterns in a ripple tank.

- produce reflection in a stretched spring and slinky.

- construct a ray diagram using a plane mirror and measure the angles of incidence and reflection.

- construct a ray diagram of an object (triangle) using a plane mirror and compare image and object.

- observe refraction in a ripple tank.

- write the definition of refraction.

- construct ray diagrams showing the relative direction of refraction waves when the incident wave enters at 90° material when it travels slow, material when it travels fast.

- the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant called the relative index of refraction; also equal to the ratio of the velocities in the media (Snell's Law).

- construct a ray diagram and using Snell's Law, calculate the index of refraction of a glass plate and glass prism.

- the index of refraction of a media is the ratio of the speed of light in a vacuum to its speed of light in the material.

- calculate the index of refraction.

- calculate the speed of light in different materials given the index of refraction.

- that the critical angle is the angle of incidence for which the angle of refraction is 90° and can be calculated by the formula $\sin\theta_c = \frac{1}{n}$

- write the definition of critical angle.

- calculate the critical angle for different materials.

- that total internal reflection occurs when light is incidents on a surface at an angle greater than the critical angle.

- draw a diagram show the respective rays produce total internal reflection using an optical bench.

- that <u>interference</u> is the effect produced by two or more waves which are passing simultaneously through a region; constructive interference occurs at points where the two waves are in phase; Destructive interference occurs at points when the two waves are out of phase.

- produce interference patterns in a ripple tank and draw diagrams of them labeling modal and antinodal lines.

- that <u>standing waves</u> are produced when two waves of the same frequency and amplitude travel in opposite directions in the same medium.

- produce a standing wave pattern in a ripple tank.

- that light or electromagnetic wave which is transverse.

- write the definition of light as such.

- the speed of light is equal to the product of its frequency and wave length, constant in air and vacuum and dependent on the medium.

- calculate the speed of light in air.

	- calculate the speed of light in other materials given the frequency and wave length.
- that a converging lens is thicker at the middle than at the edges and converges parallel rays of light.	- observe and construct images pfoduced by a double convex lens of focal length about 20 cen.
	- define the image produced by a convex lens.
- that the size and location of the image can be calculated from the focal length of the lens and the position and size of the object.	- calculate image size and distance using the formulas $\frac{1}{d_o} + \frac{1}{d_o} = \frac{1}{f}$ $\frac{So}{Si} = \frac{d_o}{Di}$
- that diverging lens are thinner in the middle than at the edges; diverge parallel ray, and produce only virtual images which are larger than the object.	- calculate image size and distance.
	- construct ray diagrams.
- that light is a wave because it exhibits interferance.	- observe interference patterns using a diffraction grating.
- that light from two coherant point sources or passing through a double slit produces a stationary interference pattern.	- observe double slit interference patterns.
- the relationship $\lambda = \frac{dx}{L}$ and its application to double slit interference.	- calculate changes in pattern size (x) or wavelength of incident light (λ) given the other information.
- that light from a point source is diffracted and produces interference patterns when passing through a single narrow slit. The width of the central maximum waves directly as the wavelength and inversely as the width of the slit and is always larger than double slit interference.	- determine width and interference pattern is single or double slit by observation.
	- calculate the λ, x, d given the proper information.
- that interference patterns produced by thin films are chanced by a difference in the optical paths of light reflected from the two surfaces of the film.	- draw an example of thin film interference according to the understanding.

- that static electricity is electrical charges at rest or the net flow of charge in any given direction is zero.

- that a positively charge object has a deficiency of electrons, and a negatively charged object has an excess of electrons unlike charges attract, like charges repel.

- that rubbing two different neutral objects together will charge them by transferring electrons and the net charge of the system is constant.

- that a neutral object may be charged by contact (conduction) with a charged object and it will acquire the same charge.

- that induction is a process by which a charged object causes a redistribution of the charges of another object without contact.

- that an object may be charged by induction by temporarily grounding it while it is near to, but not touching a charged object. It will acquire a charge opposite to that of the charging object.

- that quantity of charge or body possesses depend on its excess or deficiency of electrons. The unit of charge is the Conlonb.

  1 conl v = 6.25 x 10 18 electrons
  1 electron = elementary charge = 16×10^{-19} conl.

- define static electricity in writing.

- define positive and negative objects.

- determine repulsion or attraction of objects knowing their charge.

- charge a glass rod with silk and a rubber rod with wool and test for charge with an electroscope.

- charge an electroscope positive and negative by conduction.

- draw an electroscope charged by contact.

- charge an electroscope by induction.

- draw a neutral object being charged by induction.

- charge an electroscope by induction.

- draw the sequence of charging an electroscope by induction.

- calculate the quantity of charge possed by a body.

- calculate force between two charged objects.

- write the similarities between Conlonb's Law and Newton's Law of Universal Gravitation.

- that Conlonb's Law is represented by $\frac{F=Kq.q2}{12}$

- that electric field exists in any region of space in which an electric force acts on a charge.

- that the field around a point charge is radial and its intensity varies inversely with the square of the distance from the point charge.

- that the field around a uniformly charged rod is radially directed and its intensity varies inversely with the distance from the rod.

- that the field between two parallel charged plates is essentially uniform if the distance between the plated is small compared to the dimensons of the plates.

- that the potential difference (volt or electron volt) between two points in an electric field is the change in energy per unit charge as a charge is moved from one point to the other.

- that the fundamental unit of charge is the charge of an electron or proton and is equal to 1.6x10- 19 Conlonb's as discovered by Millikan.

- that conductivity of solids depends on the number of free charges per unit volume and metals are better conductors than non-metals.

- describe the charge in force when any variable is charged.

- calculate the magnitude and direction of electric field around a charged object using the formula $E = \frac{F}{q}$

- calculate the intensity of a field around a point charge.

- draw the field around a point charge.

- calculate the intensity of a field around a poing charge.

- write how the capacitance varies.

- calculate the field intensity using $E = \frac{v}{d}$

- calculate the potential difference between two points in an electric field.

- calculate the energy in electron volts given to an electron moving between a certain potential.

- explain the Milliken experiment.

- calculate the charge in Conlonb's given the number of elementary charges.

- write why metals are better conductors than non-metals.

- that conductivity liquids depend on movement of positive and negative ions produced by electrolyte.	- describe in writing and by diagram the conductivity of current in a liquid.
- that conductivity in gases depends on movement of positive and negative ions produced when gases are subjected to high energy radiation, electric fields, and collisions with particles.	- describe in writing conductivity in gases.
- that a potential difference is required to maintain a flow of charge (current) between two points in a conductor.	- wire a circuit so that current will flow and light a lamp.
- that the resistance Ohn, which is the opposition to the flow of current, of a conductor of uniform cross-section and composition varies directly as its length and inversely as its cross-sectional area.	- measure resistance of waves of different materials, length and cross-sectional area to prove the statement.
- that Ohm's law is v=IR and applies to metallic conductors at constant temperature in ordinary circuits.	- calculate V, I and R in simple circuits using Ohn's Law.
- that the algebraic sum of the currents entering any circuit junction is equal to zero.	- calculate current entering and leaving branches.
- that the sum of all the potential drops and and aplied voltages around a complete circuit is equl to zero.	- calculate voltage in simple circuits.
- that a series circuit is one in which there is only one current path and the following hold true: $I_t = i_1 = 1_2 = 1_3 \ldots\ldots\ldots$	- draw series circuits. - calculate V_t, I_t, R_t, v_1, v_2, v.....i_1, i_2.....

$V_t = v_1 + v_2 = \ldots\ldots\ldots$

$R_t = r_1 + r_2 + \ldots\ldots\ldots$

- that a parallel circuit is one in which there is more than one current path and the following are true.

$I_t = i_1 + i_2 + i_3 \ldots\ldots\ldots$

$V_1 = v_1 = v_2 = v_3 \ldots\ldots\ldots$

$\frac{1}{R_t} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \ldots\ldots\ldots$

- draw a parallel circuit.
- calculate voltages, amperages, and resistances for parallel circuits using the relationships for a parallel circuits and Ohm's Law.

- that power measured in joule/sec. or watts is the time rate at which electrical energy is expanded (P=vI).

- calculate power in a circuit.
- calculate voltage, amperage, or resistance given to power.
- calculate mechanical power of an electric motor.

- that energy used in an electric circuit is the product of the power developed and the time during which the flow of charges persists (Q=Pt).

- calculate the energy used in an electric circuit.
- calculate the heat energy developed in resistors.
- perform an experiment to calculate the electrical equivalent of heat.

- that a magnetic field exists in a region where magnetic forces may be detected and its direction is given by the direction in which the N-pole of a compass would point in the field.

- perform experiments mapping the magnetic field around magnets and current carrying conductors.
- determine the magnetic field around a straignt conductor using the left hand rule.

- that the flux density is the number of flux lines per unit area ($\frac{\text{Webers}}{\text{m}^2}$ or $\frac{\text{Newton's}}{\text{amp-meter}}$) and is proportional to the intensity of the field

- calculate the flux density of a magnetic field.

- permeability is the property of a material which changes the flux density in a magnetic field from its value in a vacuum.

- list material which have a high, low and moderate permeability.

- that the field of a loop carrying a current is such that the faces of the loop show polarity.

- determine the polarity of a loop using the left hand rule.

- the lines of magnetic flux around a solenoid emerge from N-pole of the solenoid and enter the S-pole

- determine the polarity of a solenoid using Ampere's Left hand rule.

- that the magnetic field strength of a solenoid is proportional to the number of turns, the current and the permeability of the core.

- perform an experiment testing the field strength of a solenoid varying the number of turns, current, and permeability of the core.

- that a force is exerted on a current-carrying conductor in a magnetic field if the conductor is not parallel to the magnetic flux. The force is perpendicular to both the field and the current.

- determine the directions of the force by using the Left hand palm rule and analysis of increase and decrease of flux density.

- the force exerted between two straight parallel conductors is attractive if the current direction are the same, and repulsive if the current directions are opposite.

- determine the direction of the force between the straight parallel conductors knowing the current directions.

- the force on a charge moving in a magnetic field is proportional to the charge, the flux density, and the component of the velocity perpendicular to the field, the direction of the force is perpendicular to

- calculate the force using F=qvB

- determine the direction of the force using the left hand palm rule.

- that a single loop or solenoid carrying a current experiences: a torque in a magnetic field which is the basis for the operation of the galvanometer and electric motor.

- determine the direction of the force.

- perform an experiment investigating the operation of a electric motor.

- that electric potential is indirected across a conductor when relative motion between the flux and the conductor produces a change in the **flux** linked by the conductor. Its magnitude is proportional to the rate at which the flux changes.

- produce a current in a conductor by moving the conduct in a magnetic field or moving the magnetic field.

- perform an experiment, show that the magnitude of the induced current increases as the flux charges.

- determine the direction of the induced current using t left hand generator rule.

- that the magnitude of an induced electromotive force is directly proportional to to the flux density, the length of the conductor, and the speed of the conductor relative to the flux.

- calculate the magnitude of Emf by using E=Blv.

- determine the direction of the induced potential using the Left hand generator rule.

- determine the magnatude of the emb and its direct throu a rotation of 360° of a D.C. generator.

- that thermionic emission is when incandescent objects emit electrons and this is the basis of vacuum tube operation.

- draw a diagram showing thermionic emission of a cathode ray tube.

- that electron beams are controlled by electric and/or magnetic field.

- determine the direction of deflection using the Left ha palm rule.

- perform an experiment showing the deflection of a team electrons by electric and magnetic fields.

- that the ratio of the charge on an electron to its mass can be determined by measuring the effects of a known magnetic field on a beam of electrons of known kinetic energy.

- calculate the $\frac{e}{m}$ ration using the following:

$$a_c = \frac{v^2}{r}$$

(electron) $E_k = \frac{1}{2} mv^2 = Ve$

$F=Bev$

- that all physical quantities can be measured in terms of a few fundamental units.

- make measurements of length, mass, and time with rulers, balance and stop watches.

- solve problems in conversing from one system of units to another.

- that the motion of a body may be described mathematically in terms of its velocity and acceleration.

- solve equations relating displacement, velocity, acceleration and time.

measure the acceleration of gravity using the spark machine.

be able to graph displacement vs time, velocity vs time and acceleration vs time.

- that for static equilibrium the external forces acting on an object or particle is zero.

- solve static force problems by the parallelogram method and analytic method.

- use the force table to determine the resultant and equilibrium forces.

- that when an unbalanced force acts on an object or particle accelerated motion results.

- calculate equations for resultant, acceleration, force velocity and time.

- read and discuss Newton's law of Motion.

- Use Newton's second law to solve problems for inertial mass.

- calculate the centriple force and acceleration acting on a revolving mass.

- that when a force is exerted over a certain distance, work is done and energy is expaided. That work and energy are equivalent.

- read and discuss the derivation and equations for work, kinetic energy, and potential energy.

- analyze mathematically the changes in potential and kinetic energy of pendulums and springs

- that energy and mementum are conserved in physical change.

- solve problems of projectile motion for height, range and velocity.

- show the conservation of mementum with the ballistic pendulum.

- make measurements of energy and velocity changes with the gallistic pendulum.

- draw diagram and graphs of one and two dimensional collisions

- figure out the impulse, force and momentum changes in assigned problems.

- show the conservation of energy for conservative forces.

Rotational Motion

- that rotational Kinematics can be described mathematically in terms of angular velocity and angular acceleration.

- solve problems for angular displacement, angular velocity, and angular acceleration.

- that in rigid-body statics the vector sum of all the external forces acting on a body in equilibrium is zero.

- solve problems to determine the necessary equilibrium force or torque to prevent rotational acceleration.

- that an unbalanced torque produces rotational motion.

- determine the relationship between torque and angular acceleration.

- show the mathematical relationship between rotational motion and translational motion.

- that the moment of inertia (rotational inertia) of a system depends upon the distribution of mass.

- determine the moment of inertia for thin shells, solid disk, point masses, etc.

- that energy and mementum is conserved in rotational motion.

- read and discuss the derivation of the equations for rotational energy and mementum.

- that electric charges have accompanying electric fields that forces on objects placed in the fields.

- that energy is conserved in electric fields.

- that electric energy is sotred in the electric field between oppositely charged plates.

- that electric fields within conductors provide us with electrical energy (electricity)

- solve problems using Coulomb's law for electric charges.

- perform laboratory experiments in charging an electroscope by induction and conduction.

- use conductors, insulators, electrometers etc. in the laboratory to study the transfer of charges.

- draw diagrams of the electric fields around positive and negative charges.

- draw diagrams of electric fields between charges.

- solve problems in determining the resultant electric field of several charges.

- draw diagrams of the equipotential surfaces around charged conductors.

- calculate the electric potential at various distances from single and multiple point charges.

- calculate the charge on a capacitor in an experiment.

- solve problems for: determining capacitance of a capacitor; and capacitance of series and parallel conduction.

- perform the Millikan Oil Drop Experiment.

- determine the force acting on a charged particle placed in the field between the plates of a capacitor.

- solve problems in determining the: equivalent resistance, voltate drop, total amperage, power consumed, heat produced for series and parallel circuits.

- do laboratory experiment to find the relationship between electrical energy and heat.

- that the properties of simple harmonic motion can be described mathematically in terms of acceleration and displacement.

- that for simple harmonic motion the displacement velocity and acceleration are functions of time.

- derive the equations for simple harmonic motion.

- solve problems of simple harmonic for acceleration as a function of displacement and time, and velocity as a function function of displacement and time.

- experiment with springs and pendulums to determine Hook's Law: relationship between the period and mass for SHM.

Heat and Temperature

- that temperature is an indication of the average kinetic energy of the molecules of a system.

- that heat indicates that energy is being transferred from one system to another.

- read and discuss the method used to determine the absolute temperature scale.

- solve problems in converting from one temperature scale to another such as from Celsius to Fahrenheit, Kelvin to Celsius, and Rankine to Fahrenheit.

- perform experiments to determine the heat of fusion of ice, heat of condensation of steam, and specific heat of solids.

- calculate problems for energy transfer during changes of phases.

- draw graphs of temperature vs heat for a system passing from one phase to another.

- study graphs showing the fusion curve, boiling curve, sublimation curve, and triple point of water and carbon dioxide.

- that energy changes in a system causes measurable physical changes in the same system.

- study the derivation of the kinetic molecular theory of gases.

	- measure electrical resistance with the Weatstone Bridge.
	- solve for currents and potential differences in complex circuits using Kirchoff's Laws.
- that a moving charge creates a magnetic field.	- perform calculation to find the magnetic force on moving electric charges and currents.
	- measure in the laboratory the magnetic field in fundamental units.
	- observe the effect of magnetic fields on moving charges in the laboratory.
- that a changing magnetic field induces and electromotive force in a conductor.	- read and discuss Faraday's law of electromagnetic induction.
	- solve problems for potential using Faraday's law.
	- measure the induced electromagnetic force produced by a generator in the laboratory.
- that an induced current will appear in such a direction that it opposes the change that produced it - theory upholding the law of conservation of energy.	- solve problems using Lenz's law.
	- discuss ways in which Lenz's law is used in electricity.
- that accelerating charges produce electromagnetic waves.	- discuss the properties of the electromagnetic spectrum.
	- discuss methods of accelerating charges to produce electromagnetic waves.
	- measure the intensity of the electromagnetic waves emmited by an oscillator.
- that energy may be transferred by waves.	- study wave motion along a slinky.
	- experiment with standing waves along a string and in a vibrating air column.

- that all objects are simultaneously absorbing and emitting radiant energy.

- that the changes in the internal energy of a system can be accounted for in terms of heat and work.

- that matter is composed of electrical charges.

- solve problems for changes in temperature volume and pressure of a gas as heat is added or removed from the system.

- determine the kinetic energy and velocity of gas molecules.

- determine experimentally the linear coefficient of expansion for solid rods of copper, brass, iron, and aluminum.

- solve problems for changes in length and volume for solids as the temperature varies.

- read and discuss the mathematical equation for determining heat transfer by conduction.

- discuss the nature of black body radiation.

- calculate the rate at which heat is radiated from different objects.

- analyze the Wien's displacement law of black body radiation.

- calculate the difference between the amount of radiant energy which an object absorbs and that which it radiates.

- read and discuss the first law of thermodynamics.

- calculate the internal energy changes of a gas as heat is added or removed for constant volume.

- determine the internal energy changes of a gas when heat is added or removed for constant pressure.

- calculate the work done by an expanding gas.

- study graphs of adiabatic and isothermal expansion of gases.

- read and discuss the atomic theory of matter as it applies to atomic and subatomic particles

- that light exhibits wave properties.

- that since light can be polarized, it is a transverse wave

Atomics and Nucleonics

- that the observed spectrum of the hydrogen atom can be accounted for in terms of discrete electron energy levels.

- show constructive and destructive interference in a ripple tank.

- observe film loops on wave properties.

- draw diagrams of wave interference.

- solve problems for wavelength, speed, frequency, period, energy and Doppler effect.

- study film loops on interference, diffraction, reflection, refraction, and Doppler effect.

- solve problems for wavelength, speed, frequency, period, and intensity of light in a vacuum snd in various optical materials.

- perform the following experiments:
  reflection from a plane mirror
  images formed by a concave mirror
  images formed by a converging lens.

- solve optical problems using the laws of lenses.

- draw diagrams of image formation for lenses, and mirrors

- discuss the nature of polarization as applied to transverse waves

- demonstrate polarization of light in the laboratory.

- demonstrate the polarization of reflected light.

- discuss the atomic structure and masses of isotopes.

- that the limitations of the Bohr model led to the development of the wave mechanical model of the atom.

- that the source of radioactivity and atomic energy is in the nucleus of the atom.

- that artificial nuclear charges can be created by bombardment of nucleii with high energy nuclear particles.

- that Einstein's theory of relativity has modified the classical Newtonian physics.

- discuss the periodic table of elements.

- analyze the Balmer series with a spectroscope and calculate the wavelengths.

- read and discuss Bohr's theory of the hydrogen atom.

- determine the energy levels of the Bohr atom.

- calculate the deBroglie wqve associated with electrons, protons, and other particles.

- solve for the wave length of the standing waves in the Bohr atom.

- discuss the work of Becquerel, Rutherford, and Curie.

- draw the paths of the alpha, beta, and gamma, rays passing through the electric and magnetic fields.

- determine the velocity and kinetic energy of alpha particles during nuclear collision.

- solve nuclear equations for alpha and beta particle emmissions.

- show the radioactive series for uranium on a graph or chart.

- write the nuclear reaction equations for alpha and beta disintegration.

- discuss the types and theory of operation of the cyclotron and linear accelerators.

- write the equations for nuclear fission and fusion.

- discuss the Michelson - Morely experiment.

- discuss the bases and significances of Einsteins' postulates.

A.P. Biology

- how an organism obtains energy in order to perform its functions.

- the process of photosythesis.

- solve problems for the changes in length, time, mass, and energy as objects approach the speed of light.

Grade 12

- describe the overall reactions for respiration and fermentation.

- explain that organisms obtain usable energy by breaking the bonds of high energy molecules.

- describe the function of adenosinetriphosphate (ATP) in endegonic reactions.

- diagram the ATP-ADP cycle and explain what happens during the cycle.

- describe the mechanism (pathways) of aweobic respiration: gylcolysis, Krebs citric acid cycle, telectron transport.

- list the functions of cytochromes and cytochrome oxidase, (cytochrome A_3).

- define oxidative phosphorylation.

- compare and contrast aerobic respiration, and anaerobic respiration.

- examine a diagram of cellular respiration, explain what happens during the four stages, and relate the details of respiration to the simple equation.

- list the products (qualitative and quantitative) of respiring or fermenting various substrates.

- describe the early historical development including the experiments of VanHelmont, Priestley, Ingenhousz, deSaussure and Engdmann.

- indicate that radiant energy is converted to the chemical energy of glucose which can be transferred to the bonds of ATP and used by living systems.

- describe the method used to measure the rate of photosynthesis.

- list the factors affecting the rate.

- explain the principle of limiting factors.

- compare and contrast light and dark reaction.

- define absorption spectra and action spectra.

- describe and diagram light reactions.

- state the source of exygen in light reactions citing evidence from experiments of VanNiel, R.Hill, & Rubens.

- describe and diagram the nature of dark reactions.

- describe the utilization of PGA in carbohydrates, lipis, proteins, and organic acid.

- compare respiration, fermentation, and photosynthesis.